FIELD DEMONSTRATION OF ENHANCED SORBENT INJECTION FOR MERCURY CONTROL

QUARTERLY TECHNICAL PROGRESS REPORT

Reporting Period: July 1 – September 30, 2005

Prepared for

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AC	activated carbon
BOP	balance of plant
CMM	Continuous mercury measurement
DJ3	PacifiCorp’s Dave Johnston Unit 3
DOE	U.S. Department of Energy
EERC	Energy and Environmental Research Center
ESP	electrostatic precipitator
LOS/LOS1	Basin Electric’s Leland Olds Unit 1
NETL	National Energy Technology Laboratory
NDIC	North Dakota Industrial Commission
PRB	Powder River Basin
SCA	specific collection area

Executive Summary

ALSTOM Power Inc., Power Plant Laboratories (ALSTOM-PPL) is currently carrying out a consortium-based, DOE-NETL program to demonstrate Mer-Cure™ technology, ALSTOM-PPL's novel and oxidation-based mercury control technology in coal-fired boilers. In the program, ALSTOM-PPL teams up with the University of North Dakota – Energy and Environmental Research Center (EERC), PacifiCorp, Basin Electric Power Cooperative (Basin Electric), Reliant Energy, North Dakota Industrial Commission (NDIC), and Minnkota Power.

The full-scale demonstration program consists of three seven-week long test campaigns in three independent host sites firing a wide range of coal ranks. These host sites include PacifiCorp's 240-MW_e Dave Johnston Unit 3 burning a Powder River Basin (PRB) coal, Basin Electric's 220-MW_e Leland Olds Unit 1 burning a North Dakota lignite, and Reliant Energy's 170-MW_e Portland Unit 1 burning an Eastern bituminous coal. These boilers are all equipped with an electrostatic precipitator (ESP).

In Mer-Cure™ technology, a small amount of sorbent (Mer-Clean™) is injected into a flue gas stream environment where the gaseous elemental mercury oxidation and removal is favorable. The sorbents are prepared with chemical additives that promote oxidation and capture of elemental mercury. The Mer-Cure™ mercury control technology offers a great opportunity for utility companies to control mercury in the most cost-effective manner while minimizing any balance-of-plant impact.

The project is being executed on schedule and budget. ALSTOM-PPL has made significant accomplishments during the performance period. Highlights of the accomplishments are:

- Completed parametric testing at PacifiCorp's Dave Johnston Unit 3;
- Completed long-term testing at PacifiCorp's Dave Johnston Unit 3;
- Disassembled the Mer-Cure™ system and shipped it to the next test site, Basin Electric's Leland Olds Station; and
- Set up the Mer-Cure™ system at Basin Electric's Leland Olds Station for testing; and
- Completed installation of sorbent injection ports at Reliant Energy's Portland Unit 1.

Analysis of data from PacifiCorp Dave Johnston testing is currently underway. Preliminary results from the parametric testing at DJ3 clearly demonstrate that ALSTOM-PPL's Mer-Cure™ system can achieve 90% removal of mercury at less than 0.7 lb/MMacf. In the next performance period, ALSTOM-PPL will complete Basin Electric test campaign and start preparation for Reliant Energy test campaign while further carrying out reduction of data from previous test campaigns.

INTRODUCTION

The overall objective of the DOE/NETL-sponsored project is to perform full-scale demonstration of Mer-Cure™ technology in three coal-fired boilers burning coals of various ranks. These host sites include PacifiCorp's 240-MW_e Dave Johnston Unit 3 (DJ3) burning a PRB coal, Basin Electric's 220-MW_e Leland Olds Unit 1 (LO1) burning a North Dakota lignite, and Reliant Energy's 170-MW_e Portland Unit 1 burning an Eastern bituminous coal. These boilers are all equipped with an ESP (Table 1).

In the program, ALSTOM-PPL will demonstrate that greater than 70% of gaseous mercury in the flue gas can be captured by injection of enhanced sorbent at a feed rate significantly lower than required by standard activated carbon. ALSTOM-PPL will also collect performance data that can be used to accelerate commercialization of our mercury control technology.

Mer-Cure™ technology applied to coal-fired power generation has the potential to be a cost-effective mercury control technology for the entire range of coals (bituminous, sub-bituminous, and lignite) and, in particular, the more challenging coals (for example, PRB and lignite coal). This control technology has low-capital costs (less than \$5/kW_e). It also requires a very small amount of additives for treatment, which results in low operating costs (0.5-0.75 mills/kWh) and minimal balance-of-plant (BOP) impact. As the technology is based on oxidation and adsorption of mercury, it is also applicable to all air pollution control configurations including wet scrubber and spray dryer-ESP/baghouse units. The main focus of the project, however, is coal-fired boilers with a cold-side ESP as the particulate control device, which represents 70% of the installed base in the United States.

The test program includes installation of equipment for the mercury control system, its operation under various firing conditions and measurement of elemental and oxidized mercury concentrations in the flue gas. The testing includes a one-week baseline mercury measurement and two weeks of parametric testing, followed by a four-week long-term testing. During the two-week parametric testing, the ALSTOM-PPL mercury control system will be operated with sorbents of several formulations at different sorbent injection rates to determine mercury oxidation and removal efficiencies. The optimum sorbent formulations and injection rates will be selected for the four-week testing to evaluate its long-term performance.

The EERC participates in the program by providing mercury measurement expertise. Continuous mercury measurement (CMM) will be carried out throughout the test period by installing CMM monitors before the injection location and after the ESP to provide both elemental and oxidized mercury concentrations in the stack gas. Ontario Hydro method will also be employed for some of the key test conditions to verify CMM data, to obtain mercury concentration and speciation measurements at ESP, and to ensure QA and QC of the measurements.

Table 1. Host site, coal and emission data for the field demonstration program

	PacifiCorp	Basin Electric	Reliant Energy
Unit	Dave Johnston 3	Leland Olds 1	Portland 1
Capacity (MW_e Gross)	240	220	172
Operation	Base-loaded	Base-loaded	Cycling
NO_x and SO_2 control	No low-NO_x Low sulfur coal	No low NO_x Low sulfur coal	Low-NO_x - LNCFS No sulfur control
Air Heater	Two Ljungstrom	Ljungstrom + Tubular	Ljungstrom
Particulate control (SCA in ft^2/kacfm)	CS-ESP (629)	CS-ESP (320)	CS-ESP (284)
Ash utilization	Sold for mine reclamation	Disposal	Disposal
Coal	Wyodak (PRB)	ND lignite	Bailey mine Pittsburgh seam coal
Higher Heating Value As-received(Btu/lb)	8,060	Lignite 6617	12,800 – 13,100
S in coal (%)	0.94	0.63	2-2.5%
Ash %	10.09	9.86	6-8%
Cl in coal (ppmwd)-dry	<50		~1,500
	PRB coal data	Lignite coal data	Bituminous coal data
Hg in coal (ppmwd)-dry	0.071	0.057-0.099	0.1-0.16
As-fired Hg level from Coal ($\mu g/Nm^3$)	7-9	6-10	10-16
Inlet Hg ($\mu g/Nm^3$)		T-7.9; PM-2.0; Ox-0.1; El-5.8- March ’03	T-9.1; PM-0.9; Ox-7.4; El-0.8$^+$
Uncontrolled Hg Emission Stack (Hg^T, Hg^p, Hg^{ox}, Hg^{el}) ($\mu g/Nm^3$)	T: 5.55-8.71 PM: 0.01-0.04 El: 2.4-4.35 Ox: 3.1-4.35	T-7.8; PM-0.0; Ox-1.4; El-6.4- March ’03	T-7.5; PM-0.0003; Ox-5.2; El-2.3$^+$ after ESP, before scrubber
Removal Efficiency		12-25% (ICR data)	36% for bituminous coals with CS-ESP
Carbon-in-ash		< 0.2%	10-12%
Flue gas temp (ESP Inlet)	330-360^{o}F	375^{o}F	277^{o}F – full load

$^+$Data from 150 MWe AES-Cayuga (CE-LNCFS III with an ESP/scrubber) burning similar Pittsburgh seam coal with 2.3% S, 0.09% Cl and 0.1 ppmd Hg

Table 2. Scheduled outages of the three host sites

Host sites	Scheduled outage	Demo period
PacifiCorp Dave Johnston 3	Apr 30 – May 31, 2005	mid June – mid Aug, 2005
Basin Electric Leland Olds 1	June, 2005	early Sept – early Nov, 2005
Reliant Portland 1	Mar 26 – May 2, 2005	mid Mar – mid May, 2006

EXPERIMENTAL

The project activities performed during the reporting period are described in this section. Following are the major tasks that have been performed for the on-going demonstration project.

- Task 1A. Design, Engineering and Fabrication of the Mer-Cure™ System for PacifiCorp's Dave Johnston Unit 3
- Task 2A. Field Demonstration at PacifiCorp's Dave Johnston Unit 3
- Task 1B. Design, Engineering and Fabrication of the Mer-Cure™ System for Basin Electric's Leland Olds Unit 1
- Task 2B. Field Demonstration at Basin Electric's Leland Olds Unit 1
- Task 1C. Design, Engineering and Fabrication of the Mer-Cure™ System for Reliant Energy's Portland Unit 1
- Task 3. Technology Transfer
- Task 4. Program Management and Reporting.

Task 1A has been completed in previous performance periods. During the reporting period, the Task 2A has been completed. Also Task 1B has been carried out. Currently, ALSTOM-PPL is executing Task 2B at Leland Olds Station. Details of the project activities are described in this section.

Task 2A. Field Demonstration at PacifiCorp's Dave Johnston Unit 3

Following the baseline and parametric testing in June, the long-term testing was scheduled for middle of July. Due to a forced outage and subsequent operational difficulties such as tube leaks in DJ3, the start of the long-term testing was delayed until early August. Despite the delay, the four-week field demonstration could be completed early September, in time for the next scheduled test campaign in Basin Electric.

During the campaign, the operational and emissions data of the Mer-Cure™ system have been collected. Solid samples have been obtained for chemical analysis. Also large quantities of ash samples (three 5-gal samples) have been collected for delivery to DOE/NETL's contractors for ash characterization.

The data analysis is under way. Preliminary data are presented in the RESULTS AND DISCUSSION section of this report as ALSTOM-PPL is currently waiting for the boiler operational data for complete analysis of the performance. Final analysis results will be included in the site report due end of January 2006.

Task 1B. Design, Engineering and Fabrication of Mer-Cure™ System for Basin Electric's Leland Olds Unit 1

In preparation for the design of the site-specific portion of the Mer-Cure™ system, site visits were made to Leland Olds Station. During the visit, more detailed information were collected such as that on the injection location (e.g., duct dimensions, turning vane arrangement), workspace, sampling port locations, trailer placement, equipment placement and the availability of utilities at work locations.

Based on the collected design plant operational data, extensive computational fluid dynamics (CFD) studies have also been conducted to design the injection system for the Mer-Cure™ system. Currently, the flue gas flow from LOS boiler is split into three streams. Approximately 25% of the total flue gas flow is directed to a tubular primary air heater, and the rest is evenly split between two Ljungstrom secondary air heaters. ALSTOM-PPL's technology requires injection of sorbent into a location upstream air heaters. In order for maximum in-flight capture of mercury, the mixing characteristics of sorbent with flue gas at the boiler outlet have been carefully examined. As shown in Figure 1a, the flow distribution of flue gases at the outlet of the boiler varies widely. Inlet to the Ljunstrom air heaters shows a large recirculation zone developed at the upper section of the horizontal inlet duct, whereas the inlet to the primary air heater indicates relatively uniform mixing.

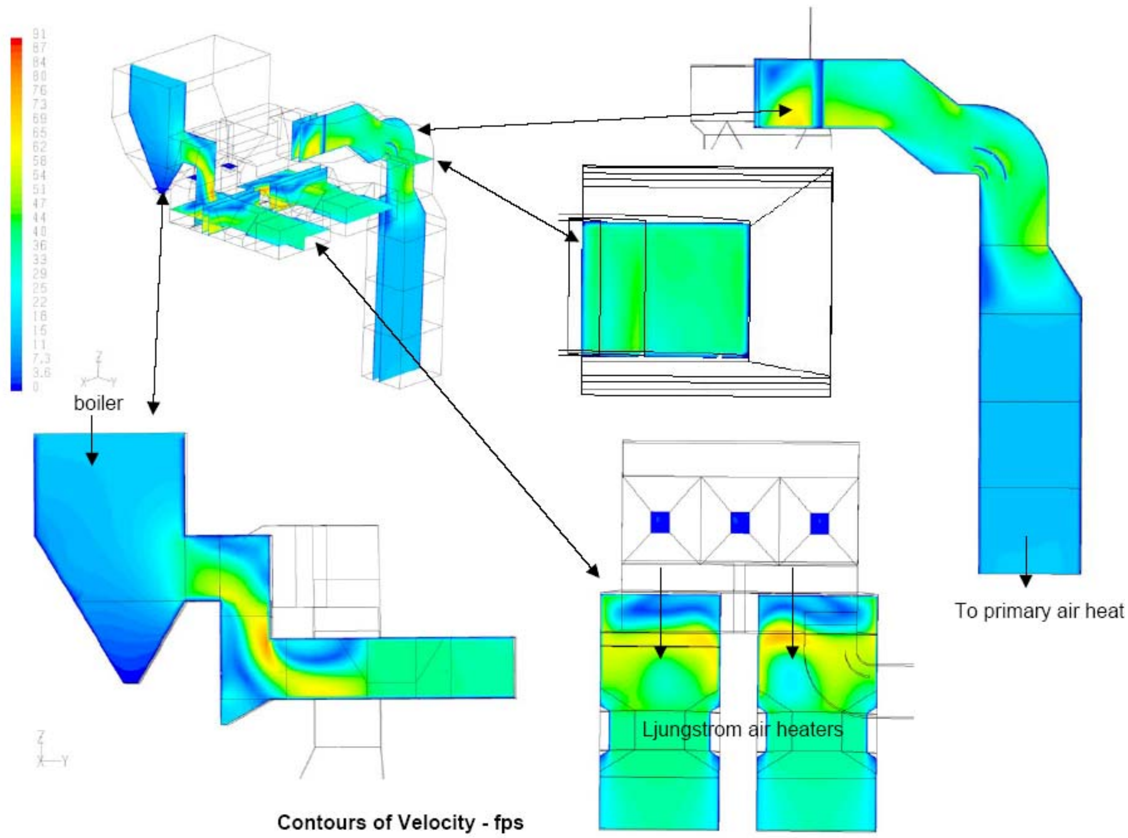

Figure 1a. CFD results for LOS boiler

Figure 1b shows the cross sectional distribution of the flue gas flow at the same location. It clearly depicts that the flow is skewed towards the lower section of the area. In fact, the upper one-third of the total cross sectional area accounts for only 10% of the total mass flow.

In order to confirm this flow prediction, velocity measurements have been conducted by EERC. Measurements were made both at the boiler exit and the air heater inlet duct for velocity as well as temperature and oxygen. Results are shown in Figure 1c for velocities as measured along the vertical centerline of the cross-sectional area in Figure 1b. The measured velocity distribution indicates that there is reversal of flow directions at the upper section of the area. A varied distribution was also observed for temperature and oxygen at the measured location.

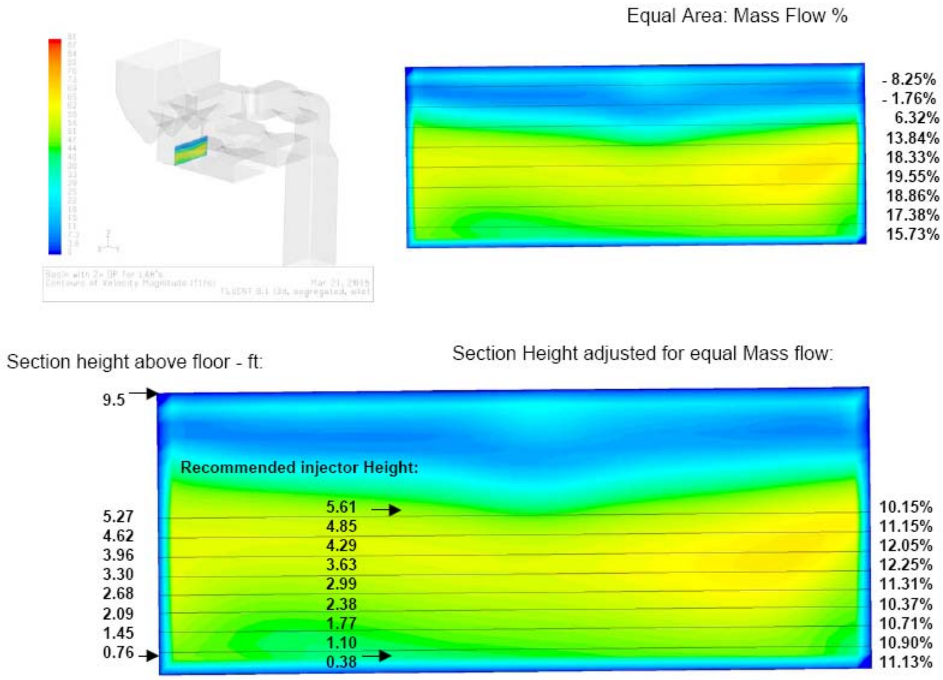

Figure 1b. Flow distribution generated from CFD studies on LOS boiler

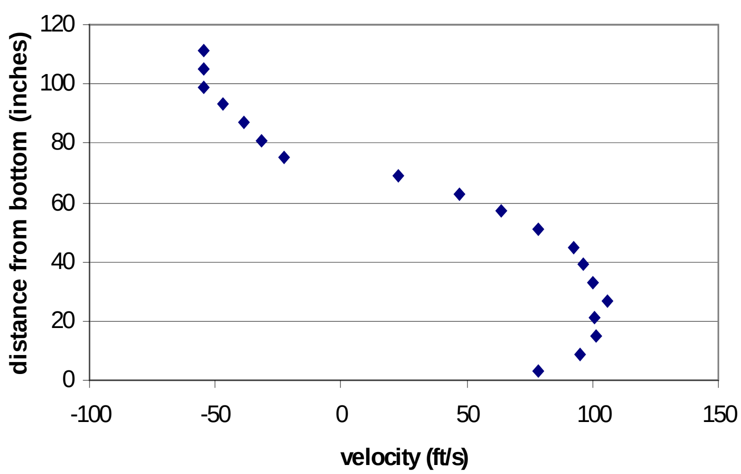

Figure 1c. Vertical flow distribution measured at the center of the injection location by a pitot tube

The lance design parameters such as the number of lances, nozzle size, number and location for each of the lances were determined based on these studies to create immediate and uniform mixing of sorbent as it is introduced into the flue gas stream. Lances have been fabricated according to the final design.

By the middle of September, Basin Electric completed site preparation in time for October testing. This included installation of sorbent injection ports and sampling ports, relocation of an office trailer, preparation of electric utilities for ALSTOM's Mer-Cure™ system and EERC's measurement systems, and preparation of sorbent storage and staging area.

Task 2B. Field Demonstration for Basin Electric Campaign

In September, the mobile Mer-Cure™ system was shipped to Basin Electric and placed on the west side of the LOS Unit 1. The sorbent storage and delivery system was assembled at the site (Figure 2); the sorbent processing system was placed close to the sorbent injection system and was connected to the storage system by 2-inch flexible hoses. The sorbent injection lances were installed at the sorbent injection location (Figure 3), and connected to the delivery system by 4-inch flexible hoses. All of the systems were secured to the boiler structure. Figure 4 shows the Mer-Cure™ system after installation.

Figure 2. Mer-Cure™ system being assembled at the LOS1 site

Figure 3. Sorbent injection lances installed at the inlet to the secondary air preheater (air preheater B) of LOS boiler

Figure 4. Mer-Cure™ system after installation at LOS

While the Mer-Cure™ system was being assembled, EERC installed their PS Analytical mercury measurement systems at the air heater inlet (west side) and at the ESP outlet, and started baseline measurements of vapor phase mercury.

During the next performance period, the parametric testing will be carried out with several treated sorbents at a range of injection rates. Long-term testing will then follow for four weeks under a couple of optimized testing conditions. Various plant data will be collected to evaluate the performance of Mer-Cure™ system. The mercury levels will be monitored at the air heater inlet and the ESP outlet. Coal samples will be collected from mills; ash samples will be collected from ESP hoppers and the ash silo. Gas analysis data will be obtained from the plant data collection system. ESP operating parameters will be also monitored.

Task 1C. Design, Engineering and Fabrication of Mer-Cure™ System for Reliant Energy's Portland Unit 1

In preparation for the design of the site-specific portion of the Mer-Cure™ system, CFD studies have been conducted for Portland Unit 1. Based on the studies, sorbent injection port number and location have been determined. Reliant Energy has completed installation of the injection ports. Details of the CFD studies will be presented in the future quarterly reports.

Task 3. Technology Transfer

The project status has been reported in the DOE/NETL Contractors' meeting in Pittsburgh, PA, from July 12 through 14 2005. A Power Point presentation has been made available through DOE/NETL on their website.

Task 4. Project Management and Reporting

During the reporting period, ALSTOM-PPL had a site preparation meeting with Basin Electric at Leland Olds Station. During the preparation meeting, the work breakdown was discussed in detail. Weekly teleconferences were held among team members in order to coordinate various aspects of the test campaign.

Basin Electric has been given material and instructions for injection port installation. Ports will be installed before completion of PacifiCorp test campaign.

RESULTS AND DISCUSSION – PacifiCorp Campaign

During the reporting period, the field demonstration at PacifiCorp's DJ3 has been performed while injecting a family of Mer-Clean™ sorbents at various injection rates. Data analysis is underway. The preliminary results are very promising in that greater than 90% of reduction has been achieved at a very low injection rate. Some of the preliminary data from parametric testing are presented in this section.

Figure 5 shows a typical response of the mercury levels from DJ3 when a Mer-Clean™ sorbent is injected. These reported mercury levels are vapor phase mercury levels corrected to 3% O_2 and 68°F. The mercury level in the early part of the testing gradually increased from 10 μg/m3 to 12 μg/m3. This may be due to variation in mercury content in coal. Although the levels changed with time, the air heater inlet mercury and the stack mercury were of the same level at any given point in time before injection (between 0:00 and 14:00), suggesting no inherent mercury removal between the air heater inlet and the stack. This suggests that the measured air heater inlet mercury can be used as an indicator for "uncontrolled" mercury level at the stack.

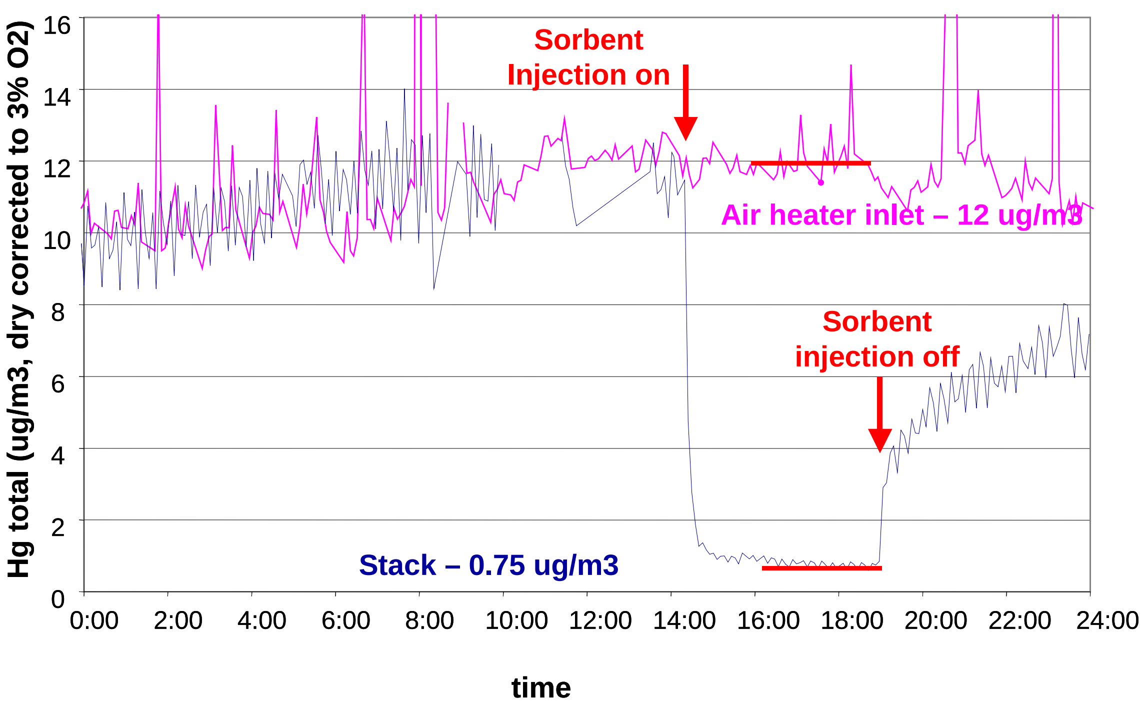

Figure 5. Preliminary data illustrating typical change of mercury levels at DJ3 before and after injection of Mer-Clean™ sorbent using Mer-Cure™ system

At 14:20, the Mer-Cure™ system was turned on and the Mer-Clean™ sorbent was injected to DJ3. The mercury level dropped instantaneously and reached a steady state level of 0.75 μg/m^3 in less than two hours. The mercury level at the air heater inlet during injection was relatively constant between 11 and 12 μg/m^3 during this period. The mercury removal efficiency based on the uncontrolled mercury level, i.e., air heater inlet mercury level, was approximately 94%. The test was continued under this condition for five hours.

When the sorbent injection was turned off at 19:00, the mercury level at the stack started recovering to the baseline level. The recovery occurred in two stages: (1) instantaneous initial recovery over 10 minute period, followed by (2) slow recovery. This recovery pattern has been observed for every test condition during parametric testing. This behavior has also been observed in previous testing conducted in our laboratory scale experiments, as well as in other field testing conducted in previous DOE-sponsored field demonstration programs.

The performance data of Mer-Clean™ sorbents obtained from parametric testing are presented in Figure 6. Each of the data points was obtained while running Mer-Cure™ system for at least four hours at a relatively constant boiler load. The removal efficiency has been calculated based on the “uncontrolled” stack emission levels measured during baseline testing. Four Mer-Clean™ sorbents – labeled Mer-Clean™ 2, 4, 6, and 8 – were tested during parametric testing. With some variations in performance among sorbents, all of the Mer-Clean™ sorbents could achieve greater than 90% removal at a relatively low injection rate. Among the four sorbents tested, Mer-Clean 8 performed the best, achieving 90% at approximately 0.6 lb/MMacf. At 1.6 lb/MMacf, 98% removal could be achieved.

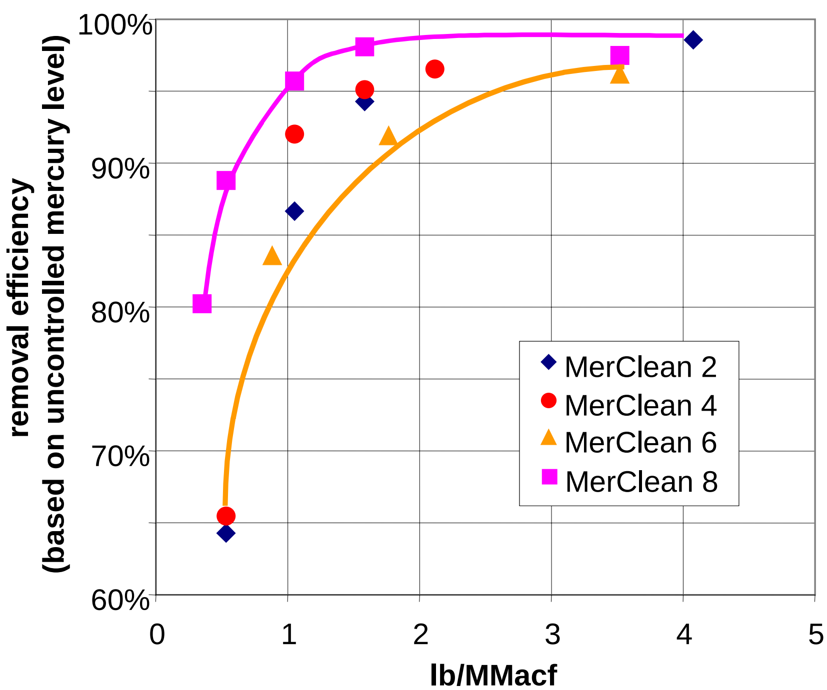

Figure 6. Preliminary data demonstrating mercury control performance of Mer-Cure™ system collected at DJ 3 during parametric testing

Although this excellent performance stems partly from the fact that DJ3 has very long ductwork between the boiler exit and the ESP, it is mostly due to the three-pronged approach being taken in the Mer-Cure™ system. The three-pronged approach is (1) uniform dispersion of sorbent particles in the flue gas stream, (2) process chemistry enhancement from carefully selected injection location, and (3) use of proprietary sorbent additives.

Preliminary results from the long-term testing conducted in the month of August and September show very similar results. ALSTOM-PPL will complete analysis of the long-term test data as soon as the plant data from PacifiCorp are made available.

CONCLUSION

Field demonstration and measurements of Mer-Cure™ system at PacifiCorp's DJ3 have been completed. Samples have been collected, and plant data are being obtained. Some of the test data have been analyzed and reported. Preliminary results from the parametric testing at DJ3 clearly demonstrate that ALSTOM-PPL's Mer-Cure™ system can achieve 90% removal of mercury at less than 0.6 lb/MMacf. Preliminary long-term test results confirm this conclusion. Analysis of the parametric and long-term data will continue in the following performance periods.

Basin Electric campaign has been started towards the end of the reporting period and is in good progress. Two weeks of parametric testing will be followed by four weeks of long-term testing.

MILESTONES AND SCHEDULE

PacifiCorp test campaign has been completed as scheduled. The second milestone of the program is completion of setting up our Mer-Cure™ system in time for eight week testing at Basin Electric's Leland Olds Station by September 27 2005. This milestone has been reached.

Parametric testing and long-term testing at LOS are currently underway. PacifiCorp test data are being analyzed for reporting. Plant data have been requested for the completion of analysis. The next milestone is delivery of the PacifiCorp site report by the end of January 2006.

Table 3. Schedule for Mer-Cure™ demonstration

ID	Task Name
1	**Design, Engineering, and Fabrication, Dave Johnston Unit**
2	Design and Engineering of System Architecture
3	Component Fabrication and Testing
4	Assembly and Shipping
5	**Field Demonstration, Dave Johnston Unit 1**
6	Project Kickoff Meeting, Environmental/Regulatory Approvals
7	Installation, Checkout, and Commissioning
8	System Setup - Milestone 1
9	Testing
10	Removal
11	Data Analysis and Site Report
12	Site Report - Milestone 2
13	**Design, Engineering, and Fabrication, Leland Olds Unit 1**
14	Design and Engineering of System Architecture
15	Component Fabrication and Testing
16	Assembly and Shipping
17	**Field Demonstration, Leland Olds Unit 1**
18	Project Kickoff Meeting, Environmental/Regulatory Approvals
19	Installation, Checkout, and Commissioning
20	System Setup - Milestone 3
21	Testing
22	Removal
23	Data Analysis and Site Report
24	Site Report - Milestone 4
25	**Design, Engineering, and Fabrication, Portland Unit 1**
26	Design and Engineering of System Architecture
27	Component Fabrication and Testing
28	Assembly and Shipping
29	**Field Demonstration, Portland Unit 1**
30	Project Kickoff Meeting, Environmental/Regulatory Approvals
31	Installation, Checkout, and Commissioning
32	System Setup - Milestone 5
33	Testing
34	Removal
35	Data Analysis and Site Report
36	Site Report - Milestone 6
37	**Technology Transfer**
38	Technology transfer
39	**Program Management and Reporting**
40	**Program Management**
432	**Reporting - As Needed**
463	Final Report
464	Final Report - Milestone 7

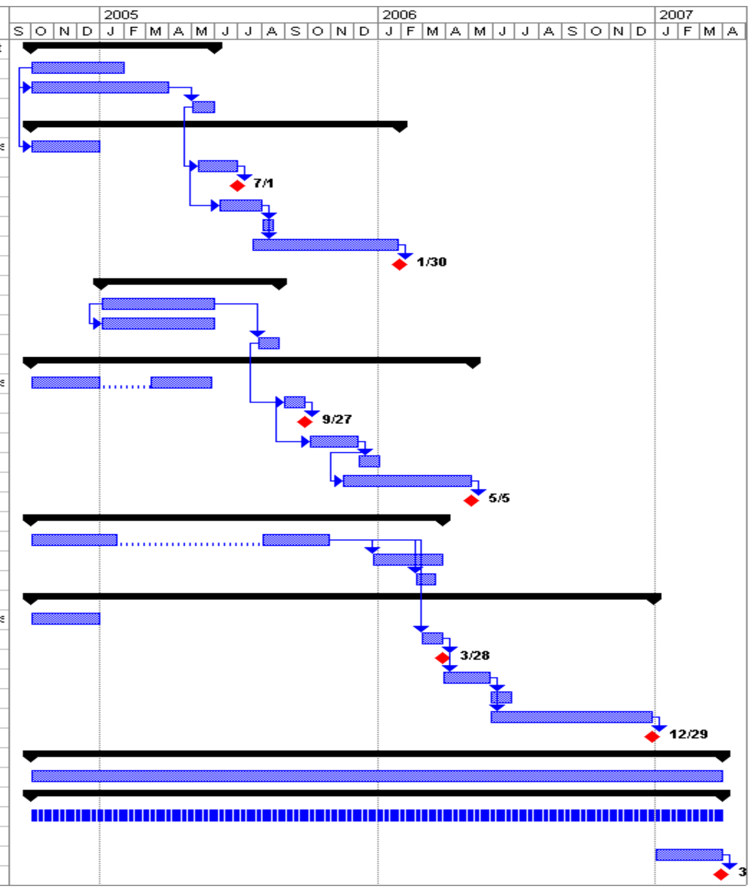

Table 4. Milestones and Deliverables

Milestone/ Deliverable	Original	Revised	Actual
1. System setup – Dave Johnston (PacifiCorp)	7/1/05		6/18/05
2. Site Report – Dave Johnston (PacifiCorp)	1/30/06		
3. System setup – Leland Olds (Basin Electric)	9/27/05		9/29/05
4. Site Report – Leland Olds (Basin Electric)	5/5/06		
5. System setup – Portland (Reliant)	3/28/06		
6. Site Report – Portland (Reliant)	12/29/06		
7. Final Report	3/30/07		